United States Department of Agriculture.

BUREAU OF SOILS.—CIRCULAR No. 12.

MILTON WHITNEY, CHIEF OF BUREAU.

[In cooperation with the Utah Agricultural Experiment Station, Prof. J. A. Widtsoe, director.]

U. S. DEPARTMENT OF AGRICULTURE,
Washington, D. C., December 29, 1903.

SIR: In May, 1902, the Bureau of Soils, under your direction and by authority of the Secretary of Agriculture, entered into cooperation with the Utah Experiment Station for the purpose of demonstrating to the people of Utah the practicability of reclaiming alkali land. A tract of 40 acres near Salt Lake City was donated for the purpose by Mr. E. D. Swan, and active steps were taken to underdrain and properly flood this land. The understanding was that the Bureau of Soils should have charge of the actual reclamation work, and the experiment station should have charge of the subsequent work of demonstrating the practicability of growing various crops on what was formerly waste land. This circular, which is a report of progress, shows that the actual reclamation has been nearly accomplished, and the tract will probably be ready in 1904 to be turned over to the experiment station workers, who will then experiment in growing different crops on the soil.

Respectfully,

THOS. H. MEANS,
In Charge of Alkali Reclamation Investigations.

Prof. MILTON WHITNEY,
Chief of the Bureau of Soils.

RECLAMATION OF ALKALI LAND NEAR SALT LAKE CITY, UTAH.

In 1899 a party from the Bureau of Soils, in cooperation with the Utah Experiment Station, made a soil survey[a] of that portion of the Salt Lake Valley lying west of the Jordan River. In this report full and careful consideration was given to the question of the alkali soils around Salt Lake City, the cause of their formation, their character and present extent, and the means of their amelioration and reclamation. The following paragraphs are taken from this report:

On the west side of the Jordan River the earliest attempts at irrigation were on the Jordan meadows, or river bottom lands, the water supply being obtained from the

[a] Soil Survey in Salt Lake Valley, Utah, by Frank D. Gardner and John Stewart. Field Operations, Division of Soils, 1899, pp. 78–114. This report was also published as Bul. 72 of the Utah Experiment Station.

Jordan River by means of small canals. Subsequently the Brighton and North Point and the North Jordan canals were run upon the first terrace above the river, and following these were the South Jordan and the Utah and Salt Lake canals on the second and third benches, respectively.

As is frequently the case, the irrigation on the benches caused an accumulation of seepage and alkali on the river bottom land, so that much of it has been abandoned. The largest and most seriously damaged area, however, is just south of Twelfth Street road, and comprises a strip of land varying from half a mile to a mile and a half in width, and extending 10 miles west from the river. Here the seepage and surplus waters from the outer extremities of the Utah and Salt Lake, the South Jordan, and the North Jordan canals have collected to an alarming extent. Indeed, the damage has gone so far that a chain of lakes has formed, presenting a water surface of fully 1,000 acres. The area affected is not less than 10 square miles.

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The seepage and waste waters from the canals account in great measure for the 10 square miles of good land which has already been ruined by seepage and alkali. It has been shown that the water is of good quality, and the lands of the upper benches are naturally free from any great excess of alkali; but the continual seepage from the canals during the growing season for a great many years has transported a quantity of salt to the lower levels.

The necessity of careful construction of the canals, especially those on gravelly lands, and the desirability of preventing the waste water from flowing over the lower levels is sufficiently obvious without further comment.

The application of water on the lowlands west of Salt Lake City, where there is a large amount of alkali in the lower depths, has been attended with very disastrous results to crops. The salt has quickly risen to the surface and, even where the surface foot was originally free from alkali, the crops have been completely ruined in the course of two or three years.

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Attention has already been called to the necessity of underdrainage for protection against injury from seepage waters and alkali and for the reclamation of injured lands. Irrigated lands in the Salt Lake Valley are worth at least from $60 to $100 per acre. Land immediately adjacent to Salt Lake City, especially if held as suburban property and if free from alkali, would be worth much more than this. There is plenty of good tile clay in the vicinity of Salt Lake City, and tile could be manufactured for the farmer at a reasonable cost. It is estimated that it would cost from $10 to $20 an acre to underdrain these lands which, under the present conditions have a merely nominal value.

Lands in New York, Ohio, and Illinois, worth from $50 to $75 per acre, have been very extensively underdrained in order to increase their productiveness, to hasten the maturity of the crops, and to insure the crops from injury by drought. It would certainly be a reasonable proposition to protect these valuable lands and to reclaim in the same way what would be valuable land. Money so invested is in the nature of an insurance against loss of crops from seepage waters and alkali.

During the course of this investigation particular attention was given to the possibility of reclaiming the vast tract of 125 square miles between Salt Lake City and the Great Salt Lake. The levels of the railroad surveys and of the canal companies were freely consulted. At Salt Lake City the level of the Jordan River is about 20 feet above the level of the water in the Great Salt Lake. The distance across is about 14 miles. There is a slight ridge, however, running a little west of north about a third of the way across from Salt Lake City. From the crest of this ridge to the Great Salt Lake there is a uniform fall of approximately 3 feet to the mile. This would be ample for the main drainage canals, as the irrigating canals have only about one-half this fall. Furthermore, there are many draws, already 4 to 8 feet

deep, extending like fingers through this area, which with little additional work could be made to answer for a considerable part of the drainage system.

On account of the impervious nature of the Jordan clay, the great salt content, and the low elevation, it would not be advisable to attempt drainage over this class of land at the present time. Subtracting this area, estimated at 35 square miles, from the 125 square miles, the value of the remaining lands, if thoroughly drained, would be about $3,000,000. At present they have merely a nominal value.

Since the publication of this report no step has been taken by State or county authorities toward any general scheme of drainage and reclamation, and so far as the knowledge of the Bureau goes, no work of any moment has been attempted by individuals.

In order to bring a matter of so much importance to the attention of the farmers, as well as of the community at large, an experiment to demonstrate the value of drainage in alkali reclamation was planned by the Bureau of Soils. In the carrying out of the work the Utah Experiment Station entered into cooperation with the Bureau of Soils, and in 1902 a tract of 40 acres belonging to Mr. E. D. Swan was selected for the demonstration. This tract lies 4 miles west of Salt Lake City, in sec. 5, T. 1 S., R. 1 N., and is about half way between the two railroads running directly west from Salt Lake City to Salt Air and to Garfield Beach. The nearest railroad station is Buenavista, distant one-fourth of a mile from the tract, on the San Pedro, Los Angeles and Salt Lake Railway.

The land, at the time work was commenced, was all strongly impregnated with alkali salts, and had nothing growing upon it except a few alkali weeds, the most prominent of which was greasewood (*Sarcobatus vermiculatus*). The land was considered valueless by the farmers of the neighborhood.

The tract lies on the east side of Williams Lake, and at its highest point has an elevation of about 8 feet above the part of the lake bed adjacent to the tract. The sketch map on page 5 shows the plan of the tract, and the size, depth, and distance apart of the draintile installed.

The cost of this installation was as follows:

270 feet 10-inch tile, at $100 per M feet	$27.00
300 feet 8-inch tile, at $64 per M feet	19.20
520 feet 6-inch tile, at $27.50 per M feet	14.30
6,580 feet 4-inch tile, at $17 per M feet	111.86
2,890 feet 3-inch tile, at $13 per M feet	37.57
Fittings	2.80
Freight on 3 carloads, Ogden to Buenavista	60.00
Cartage and scattering tile	17.50
606 rods ditch, at 50 cents per rod	303.00
67 rods main ditch, at 54 cents per rod	36.30
673 rods covering with team	19.50
150 feet outlet ditch (open)	6.00
One-fifth cost of tools	5.00
Total cost	660.03

The average cost of the drainage system completed was $16.50 per acre, and it is believed that the drainage of larger tracts could be accomplished at about the same cost. Some of the stated items of expense could be considerably reduced, but others would be greater. For example, while it might be possible to obtain better prices on tile, if purchased in larger lots, the drainage of any more extensive area would require the digging of an outlet either to the Jordan River or to Great Salt Lake.

The tract is composed of a surface soil of loam and sandy loam, with a depth ranging from 12 to 18 inches. The underlying material is a heavy clay. A very shallow sand stratum occurs at a depth of 4 feet over the greater part of the tract. The lower, or lakeward, half of the tract is underlain at an average depth of 26 inches by white calcareous hardpan, from 1 to 2 inches in thickness. Occasionally two strata of this hardpan are found, the first lying about 4 inches above the second.

Another special soil feature occurs in places in the tract. This consists of a layer of peculiar brown material, somewhat inclined to fracture along lines after the manner of adobe, and yet maintaining in the interior part of the layer a hard impervious core. This material is found at from 4 to 12 inches beneath the surface. When it is turned with the plow in a dry condition, it breaks into particles ranging in size from inch cubes to granules about as large as buckshot. When wet, it still breaks on regular lines of fracture, but materially softens, and if thoroughly plowed loses its hardpan properties. In excavating during the drainage installation it was necessary to break the dry material with a pick, as was also the case with the white hardpan.

With the above soil and hardpan conditions it was deemed advisable to place the drains 150 feet apart, and this interval was used, except in one instance. The system for the 40 acres includes eight lateral drains and one main drain. Each of the laterals is 1,250 feet long, and is laid with 850 feet of 4-inch and 400 feet of 3-inch draintile. The exception already referred to is in the interval for lateral No. 8, which is laid 200 feet from the nearest lateral, the object being to study its efficiency under such conditions of soil as exist in this tract.

The main drain is put in across the lower part of the tract, 20 feet from its west side, and is met by seven of the laterals. This drain was laid with 270 feet of 10-inch, 300 feet of 8-inch, and 520 feet of 6-inch tile.

The 10-inch tile in the main drain have a capacity sufficient to remove 4 inches of water per week from the adjacent lands, or lands underlain by laterals Nos. 1 to 7. Ordinary operations for reclamation do not overload the drains, however, since the factors of summer evaporation and subdrainage through the soil play important parts in the disposal of the water added in flooding operations.

Over the great part of the tract the drains were laid at a depth of 4 feet. In that part nearer the lake a somewhat shallower depth was necessitated in order to obtain a gravity outlet for the drainage water. The drains were laid on a grade of not less than one-tenth foot in 100 feet, except where 3-inch tile was used when the grade was somewhat higher. The illustration (fig. 1), is a plan of the completed system, and shows the supply canals, position of the weirs, drains, and the position and extent of the different sizes of tiles. The system as installed has proven adequate. Flooding has been carried on systematically, the land being divided into checks and plats by levees, and each plat treated in rotation. During each flooding water has been added to an average depth of 4 inches. The movement of the water into the soil has been

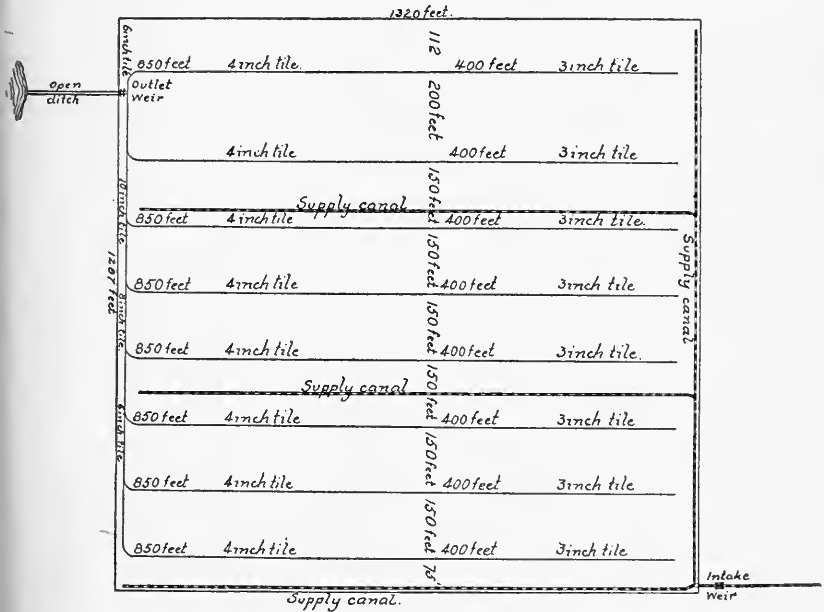

FIG. 1.—Plan of drainage system, Swan tract.

regular, and, considering the character of the clay subsoil, rapid, and the drains have quickly filled after the floodings and have run freely throughout the experiment.

During the last season (1903) the land was flooded once each week, with occasional longer intervals when the supply canal was being repaired or during times when the land was being plowed or the levees repaired.

Before any water was applied to the tract a detailed survey was made to determine the alkali content of the soil. This initial survey was made in September, 1902. The land was then flooded once and allowed to remain until the next spring.

In May, 1903, before work was commenced, a second survey was made; and a third survey of the tract was made in October, 1903, after the close of the season's operations.

The following table gives the tonnage of alkali in the tract, as shown by these surveys:

Quantity of alkali in the first 4 feet of soil in the Swan tract, Salt Lake City.

Soil sections.	September, 1902.		May, 1903.			October, 1903.		
	Alkali in 40 acres.	Per cent of total.	Alkali in 40 acres.	Per cent of total.	Per cent lost.[a]	Alkali in 40 acres.	Per cent of total.	Per cent lost.[a]
	Tons.		*Tons.*			*Tons.*		
In first foot	1,363	20	499	14	63	101	8	92
In second foot	1,540	23	650	19	58	183	15	88
In third foot	1,766	27	1,066	31	40	330	28	82
In fourth foot.......	1,982	30	1,265	36	36	607	49	69
Total..........	6,651	....	3,480	....	49	1,221	....	82

[a] Shows the proportion of the salts removed as compared with the salt originally present in the various depths.

The data given in the above table shows that between September, 1902, and the following May, 3,171 tons of salt had been removed from the soil to a depth of 4 feet, and that between September, 1902, and the following October, 5,430 tons had been removed, or 82 per cent of the alkali originally in the first 4 feet of soil. It is also seen that a greater proportion of the alkali has been washed out of the surface foot than out of the lower depths, and that the movement of the salts is less pronounced as the depth increases. Thus originally the fourth foot carried 30 per cent of the total salt, while in October, 1903, the fourth foot carried 49 per cent of the salt then remaining in the soil. There has been, however, a marked decrease in the quantity of salt at all the depths, and the fourth foot has in reality lost 69 per cent of the quantity of alkali originally present.

It must be understood that these changes have taken place through the movement of the salts downward by percolating water and not through washing them from the surface of the land.

The following table shows the number of acres of land in each of the six grades into which the Bureau classifies alkali lands, for the various depths to which determinations were made in the tract. The table gives the area in each grade in September, 1902, and the area in each grade in October, 1903, after one year's operations in the reclamation work.

Areas of land of different grades of alkali, September, 1902, and October, 1903.

Alkali present in soil. (Grade.)	First foot.		Second foot.		Third foot.		Fourth foot.		All four feet.	
	Sept., 1902.	Oct., 1903.	Sept., 1902.	Oct., 1903.	Sept., 1902.	Oct., 1903.	Sept., 1902.	Oct., 1903.	Sept., 1902.	Oct., 1903.
	Acres.	*Acres.*	*Acres.*	*Acres.*	*Acres.*	*Acres.*	*Acres.*	*Acres.*	*Acres.*	*Acres.*
0 to 0.20 per cent...	None.	35.6	None.	21.4	None.	6.7	None.	1.0	None.	16.2
0.20 to 0.40 per cent.	3.0	1.6	.4	11.0	.1	16.8	.1	15.0	.9	11.0
0.40 to 0.60 per cent.	3.3	1.1	2.3	4.5	.7	8.8	1.3	5.4	1.9	5.0
0.60 to 1 per cent...	10.7	.5	8.0	1.5	3.9	4.5	6.2	8.1	7.2	3.6
1 to 3 per cent......	16.8	None.	19.7	.4	22.6	2.0	18.1	9.3	19.3	3.0
Over 3 per cent	5.0	None.	8.4	None.	11.5	None.	13.1	None.	9.5	None.

The above table shows clearly the increase in the acreage of soils containing a low percentage of alkali; the columns headed September, 1902, showing the original condition of the tract, and those headed October showing the condition at the time of the last examination.

The following table shows the volume of water added to the tract from September, 1902, until October, 1903. The table shows also the volume of drainage over the outlet weir, and the salts (alkali) removed from the tract in the drainage water. The results are obtained from continuous measurements and daily collections of water samples for the entire period.

Total quantity of water used in flooding the tract, quantity flowing off through drains, and quantity of salts removed in drainage water.

Month.	Volume of water added to tract.	Volume of drainage water from tract.	Salts in drainage water.
	Cubic feet.	*Cubic feet.*	*Pounds.*
1902—September	284,400	158,700	152,200
October	940,000	265,000	195,100
November	a 171,300	251,000	353,800
December	a 166,500	139,700	187,800
1903—January	a 291,800	257,300	391,200
February	a 136,400	174,400	214,800
March	a 132,000	428,000	590,700
April	a 112,000	26,900	26,500
May	a 576,900 760,900	521,500	567,100
June	a 106,000 676,500	274,500	345,200
July	a 36,580 1,691,970	480,490	556,459
August	2,122,160	814,890	1,221,742
September	2,352,920	1,195,976	1,654,115
October	351,290	663,420	840,981
Total	10,909,620	5,651,776	7,297,697

a Fell as rain or snow.

Total volume of canal water used	cubic feet..	9,180,140
Volume falling as rain and snow	do....	1,729,480
Total volume from above sources	do....	10,909,620
Total water used	acre feet..	250.4
Salts added in the canal water	pounds..	900,000

The total volume of drainage was 5,651,776 cubic feet, or 51.8 per cent of the water added to the tract. This 51.8 per cent drainage water carried 3,648 tons of salts over the outlet weir. The remainder of the salts removed from the tract have passed into the deeper subsoil and been carried away by the natural subdrainage.

The results so far obtained indicate the ultimate complete reclamation of the land. The single season's operations produced marked improvement in the land, not only in the alkali content, as shown by the soil tests made, or as shown by the salts in the drainage, but also as shown in the improved tilth of the soil and the favorable changes that have taken place in its physical properties.

The indications are that the greater part of the tract is at present sufficiently sweetened to allow the growing of shallow-rooted crops. It is the intention to continue the work until reclamation is complete, and the data pertaining to the process of flooding and drainage will be supplemented by practical crop tests during the season of 1904.

W. H. Heileman.

Approved.

James Wilson,

Secretary of Agriculture.

Washington, D. C., *February 2, 1904.*

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